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Short communication

Reuse of waste oils in the treatment of wood aggregates

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Abstract

In this work, oil intended for disposal is used to impregnate wood shavings at room temperature and atmospheric pressure. Experimental results show a sizable decrease in the absorption of water by these wood shavings and the generation of a wood–cement–mineral fines composite from industrial waste. The composite's dimensional variations can be reduced by half without any of the mechanical properties or thermal conductivity being adversely affected. An oil intended for disposal is more efficient than linseed oil in reducing the extreme dimensional variations. © 2000 Elsevier Science Ltd. All rights reserved.

1. Introduction

Oils intended for disposal can be classified as industrial wastes which require special elimination precautions and procedures. Furthermore, construction and demolition generate large quantities of wood wastes which, even if they have not been processed with salts, heavy metal oxides or creosotes, must still be incinerated or stored at a site II-classified dump. Moreover, the utilization of alluvial or crushed aggregates produces major quantities of mineral fines which often constitute an environmental hazard. The authors have previously shown that these wood wastes and quarry wastes could be reused together in the form of wood concretes [1–11].

Wood aggregates belong to the category of organic aggregates commonly employed in the manufacturing of lightweight concrete. An inventory of the aggregates available on the market has recently been conducted by Pimienta [12]. The aggregates undergo processing intended to decrease the recovery of water both during mixing and while in service. Pimienta classified these processes into several broad categories. Thermal processes (heating, hydrolysis at high temperature and under pressure) allow lowering or removing altogether the hemicellulose content which is responsible for the swelling of the wood [13–15]. The aim of the chemical processes is to avoid the fixing of water molecules by wood hydroxyl groups [16–19]. Mixed processes combine several techniques. Physical processes are also implemented with the main purpose of limiting the transfer of water to the external environment without any chemical alteration of the aggregates. These processes are interface processes with more or less slight impregnation. They require either a coating, a mineralization process or wood swelling. The coating, intended to ensure the insulation of the wood by making it resistant to external agents, uses waterproofing materials, saturated or unsaturated hydrocarbons, siliceous particles, polymers, etc. [20]. Mineralization is carried out by impregnation using mineral salts [21]. The swelling consists of filling in the cellular gaps of wood thanks to impregnation-vacuum pressure techniques [22,23]. by the use of compounds which block the freeing of the substance which can act to plug the Portland cement.

The oil-based process is classified into this latter category. Previous studies have focused on the use of paraffin oils in impregnation-vacuum pressure processes [22] and have demonstrated that such oils did not exert an impact either on the drying or on the mechanical properties of wood concrete.

The recycling of waste oils during the aggregate impregnation process can therefore provide a valuable opportunity, particularly insofar as it can be performed at room temperature and atmospheric pressure. It is

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possible as long as the thickness of the wood aggregates remains low. For this reason, in the work presented herein, the wood aggregates used consist of wood shavings from the building industry, which also constitute a significant source of waste. The influence of the process on hydrous, mechanical and thermal properties has been analyzed by means of a study using microscopy techniques. The performance has been compared with that obtained using a "pure" vegetable oil which is commonly applied in the protection of wood.

2. Materials and experimental set up

2.1. *Raw materials*

- The mineralogical study has shown that the clayey fines used in this work are composed of kaolinite with small percentages of quartz and mica [24]. These clayey materials are wastes from the production of alluvial aggregates and are not highly plastic [plasticity index (PI) = 12%], with an upper granular limit value of 70 μm. Grain sizes with a diameter of less than 2 μm represent 55% of the cumulative passing.
- The cement is a CPA CEMI 52.5.
- The wood used in this study is a fir, due to its low bulk density and widespread application potential within the building industry. The apparent density of the wood shavings is 0.05 and the real density 0.44.
- Schistous fines are composed of residue from the crushing of Brioverian schist which had undergone a slight metamorphism. The portion included herein corresponds to what remained once the fraction of sand and fine gravel particles had been removed. The separation process was performed on dry material. The fines used in this work are characterized by gap-grading from 88% passing at 500 μm to 100% passing at 1 mm. The proportion of grains less than 2 μm in size is practically zero, and the residue provided a granular material lacking in both cohesion and plasticity. Their apparent density is 1.05 and their absolute density 2.70.
- The oils used are linseed oil with a density of 0.86 and oil intended for disposal with a density of 0.9.
- The mixing water is drinking water from the public water supply network. Its pH is verified regularly and has a value of approximately 7.7.

2.2. *Production of the composite*

This process is carried out by the pulverization of oil during the brewing of shavings in a "planetary-movement" mixer, up until homogenization. The processed shavings are then conserved in a "dry" cell ($T = 20°C$, R.H. = 50%) during a minimum of 28 days.

Mineral fines and cement are initially introduced in a dry state into the mixer which complies with standard EN 196-1 and then mixed at low speed. Next, processed shavings are gradually sprinkled into the dry mix while continuing the low-speed mixing. Water is then gradually added without stopping the mixing. Once the paste turns homogeneous, it is poured into molds. Conservation takes place in a moisture cell ($T = 20°C$, R.H. = 95%).

The composition and characteristics of the basic composite are given in Table 1. The intensity of the process is measured by the oil/shavings mass ratio. Performance is compared on the basis of a constant bulk percentage of wood.

2.3. *Measurement techniques*

Mechanical tests were carried out, according to the european standard EN 196-1, at 28 days on 4×4×16 cm prismatic samples conserved in a dry cell. The tensile strengths were measured indirectly by flexure. The compressive strengths were determined using a 20 kN capacity Walter Baibag press, with a speed loading provided in the NF P 18-406 Standard concretes.

Dimensional variations are determined on 4×4×16 cm prisms, according to the French Standard NF P 15-433, with the help of a retractometer which allows assessing variations down to a level of 10^{-3} mm and which is connected to a printer for entering the data measurements.

The variations in mass were determined using a scale accurate to 1/100th of a gram. The determination of the saturation water content of the shavings was difficult. The method employed, which consists of weighing the aggregates in the dry state, then placing them in a sieve and immersing the entire set-up until saturation, generates wide variability in the results; a random quantity of water remains bonded to the surface of the shavings. This water could be eliminated by means of centrifugation (three cycles of drying to120 revolutions/min for 30 s).

The thermal conductivity of the composite was measured on 5×10×10 cm samples thanks to an experimental device recently developed in the laboratory [24]. and using the Transient Plane Source [25].

Table 1
Characteristics of the basic composite

Dry density (kg/m^3)	850
Compressive strength (MPa)	8.9
Tensile strength (MPa)	3.8
Capillary absorption (bulk percentage)	46
Extreme dimensional variations (mm/m)	3.5

3. Experimental results and analysis

The process performed was intended to make the aggregates less sensitive to water. In order to evaluate the impacts on the composite's performance, the water absorption of both the shavings and the composite, along with the dimensional variations of the composite, will be systematically studied. The thermal and mechanical performances of the wood-concrete composite are to be determined in the dry state.

3.1. Density

Fig. 1 presents the composite's dry density versus the ratio oil/wood in weight. Results show that the density increases as the quantity of oil increases. Since the density of the oil intended for disposal is higher than that of the linseed oil, it could be expected that the dry densities of the composite would be of the same order of magnitude. Yet, the opposite turns out to be true. This phenomenon most likely depends on the viscosity of the oil intended for disposal, which limits its absorption by the wood shavings. Moreover, porosity related to the presence of oil droplets can be observed in the matrix. This porosity is greater than that in the case of linseed oil, which again tends to decrease the density of the composite.

3.2. Hydrous behavior

Figs. 2 and 3 represent the water absorption of the shavings and of the composite, respectively.

The process is effective in both of these cases. Nevertheless, for the linseed oil process with a bulk ratio of 0.75, the water absorption of the composite is greater than with a ratio of 0.5. This finding can be attributed to the presence of an additional porosity in the matrix. During impregnation, a portion of the oil stays on the surface of the shavings and migrates into the matrix during mixing. These oil droplets, immiscible in water, occupy a volume fraction of the fresh mix. During the composites' hardening, these droplets also get set and then contract. In this way, they create spaces which are accessible to water, such as the spaces visible in Plate 1. In the case of an oil/wood ratio = 0.75 for instance, an excess would be present in comparison with the shavings' absorption capacity, a situation which would induce a larger quantity of oil in the matrix. This finding is confirmed by the change in color of the samples at this ratio value.

The results presented in Fig. 4 show that as the oil-based ratio increases, the extreme dimensional variations in the composite also increase, i.e. the difference between the length of the sample in the dry state and its length in the water-saturated state is decreasing. For equal ratio values, processing with oil intended for disposal is more effective than processing with linseed oil.

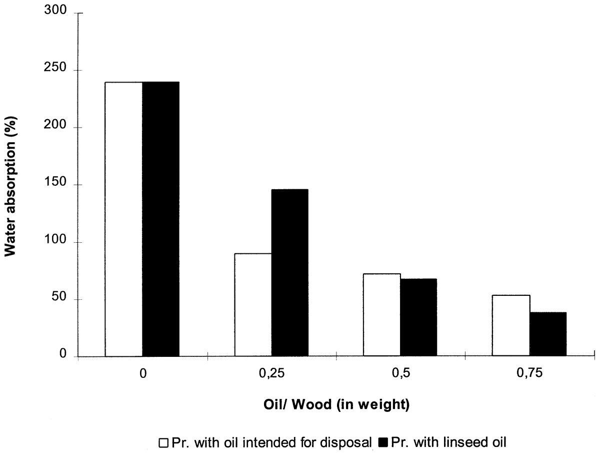

Fig. 2. Influence of the wood shavings process with oil on the water–weighted variations of the shavings.

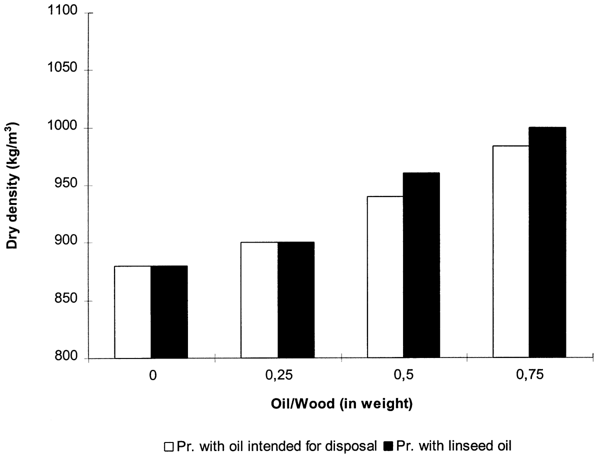

Fig. 1. Influence of the bulk oil/wood ratio on the dry density of the wood–cement–mineral fines composite after 56 days.

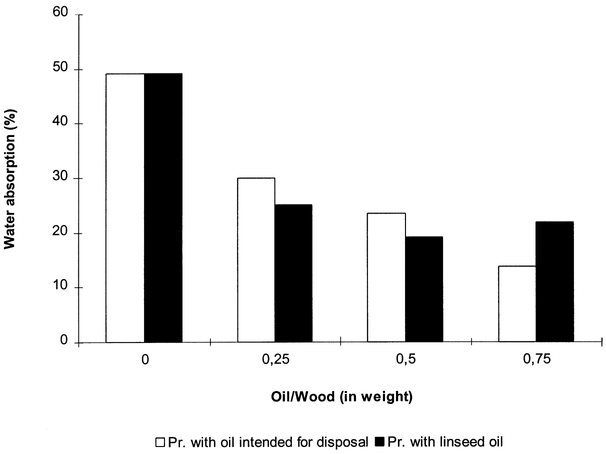

Fig. 3. Influence of the wood shavings process with oil on the water–weighted variations of the wood–cement–mineral fines composite.

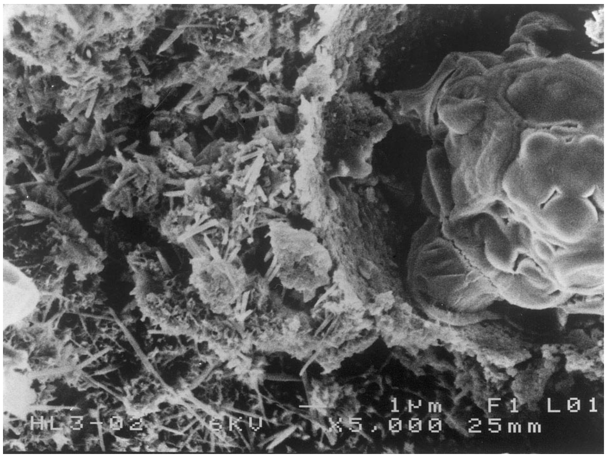

Plate 1. Cement–mineral fines composite with wood shavings treated with linseed oil (oil/wood = 0.75) G = 5000. Detail of an oil droplet occupying a pore in the matrix.

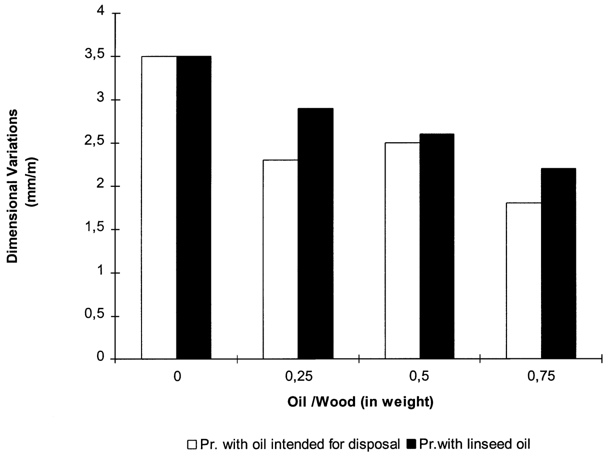

Fig. 4. Influence of the wood shavings process with oil on the dimensional variations of the wood–cement–mineral fines composite.

Nevertheless, the decrease in dimensional variations remains small in comparison with the corrected water absorption. Figs. 5 and 6 show that a relationship exists between the extreme dimensional variation of the composite and the water absorption of the shavings.

3.3. Mechanical strength

Figs. 7 and 8 present the tensile and compressive strengths of the composite, respectively, versus the ratio oil/wood in weight. These strength values decrease as the intensity of the process increases, with the effect becoming more pronounced for oil intended for disposal than for linseed oil.

This finding can be explained not only by the additional porosity introduced into the matrix, but also by a poorer shavings/matrix adhesion (see Plate 2), especially for the tensile strength.

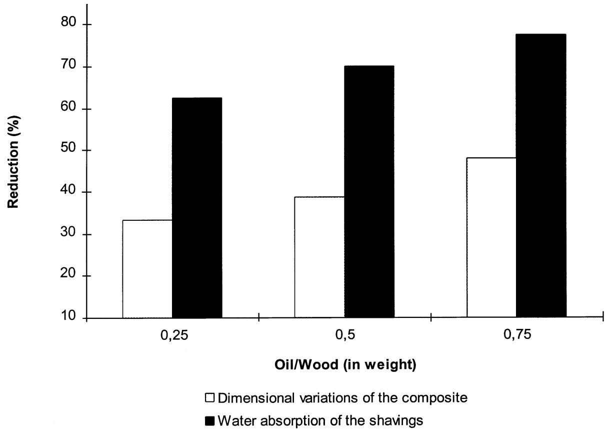

Fig. 5. Influence of the wood shavings process with oil intended for disposal on the reduction of the water absorption of the wood shavings and of the dimensional variations of the composite.

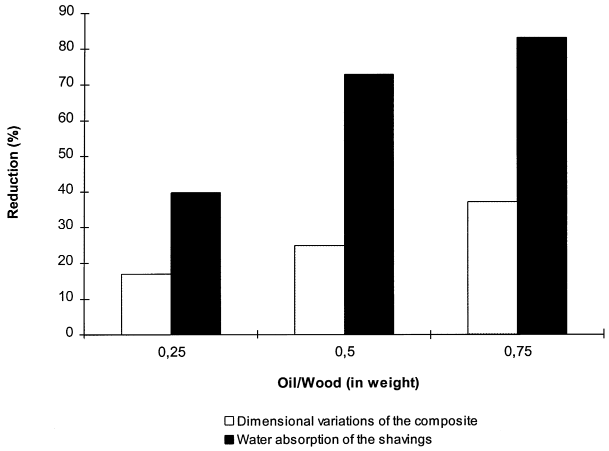

Fig. 6. Influence of the wood shavings process with linseed oil on the reduction of the water absorption of the wood shavings and of the dimensional variations of the composite.

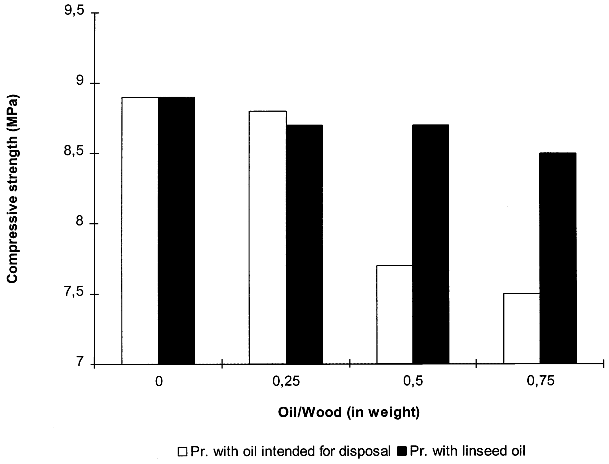

Fig. 7. Influence of the wood shavings process with oil on the compressive strength of the wood–cement–mineral fines composite after 56 days.

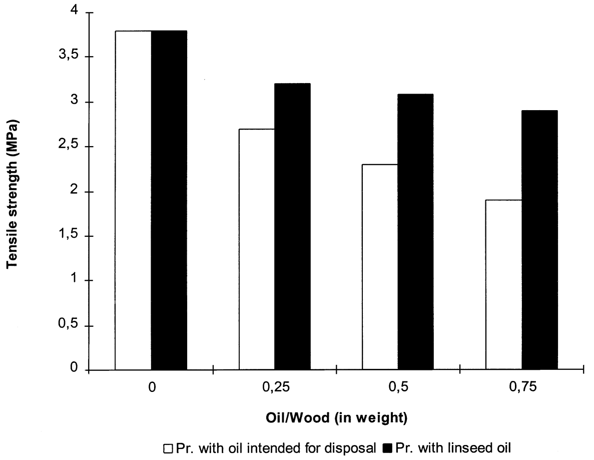

Fig. 8. Influence of the wood shavings process with oil on the tensile strength of the wood–cement–mineral fines composite after 56 days.

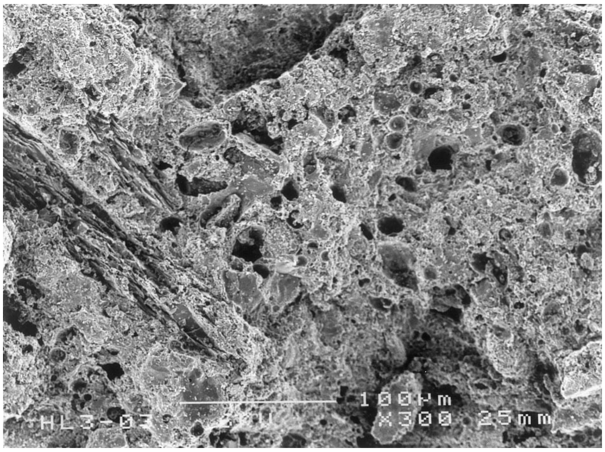

Plate 2. Cement–mineral fines composite with wood shavings treated with linseed oil (oil/wood = 0.75)$G = 300$.

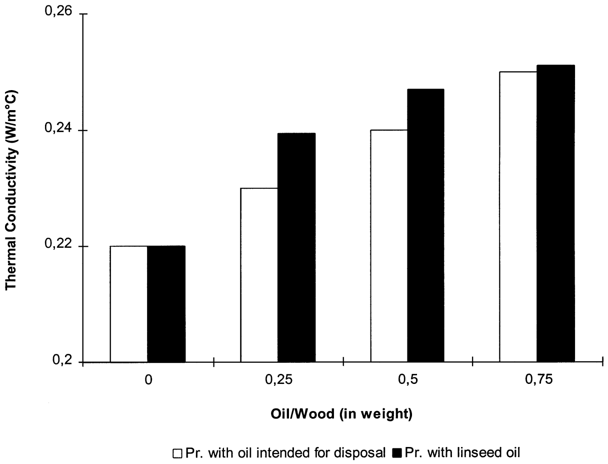

Fig. 9. Influence of the bulk oil/wood ratio on the thermal conductivity of the wood–cement–mineral fines composite.

3.4. Thermal conductivity

The thermal conductivity of the composite, as a function of the bulk processing percentage, is presented in Fig. 9. Thermal conductivity increases proportional to both the intensity of the processing and the evolution in the density. Since the thermal conductivity of oil is higher than that of air, the filling of wood cells induces a rise in the composite's conductivity. This effect is intensified by the presence of oil droplets in the matrix whose thermal conductivity is lower than that of the clay–cement matrix.

4. Conclusion

Experimental results have shown that the processing of wood shavings with oil intended for disposal allows significantly decreasing the water absorption of the shavings as well as that of a wood-cement-schistous fines composite. The dimensional variations of the composite can be halved without any of the mechanical properties or thermal conductivity being adversely affected. Use of an oil intended for disposal is more effective than linseed oil in reducing the extreme dimensional variations. The values (<2 mm/m) are small with respect to those typically measured for wood-based concrete with a cementitious matrix of the same density (5 mm/m).

These values however all exceed the target value established by the European program "FOREST" (1 mm/m). It must nonetheless be recalled that these dimensional variations correspond to extreme conditions (the saturated state and the dry state), which are not indicative of normal service conditions.

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